Space Technology Research Grants

Energy Accommodation from Surface Catalyzed Reactions in Air Plasmas

Completed Technology Project (2016 - 2018)

Project Introduction

Understanding energy transport at the gas-surface interface between catalytic/reacting surfaces exposed to highly dissociated plasmas remains a significant research challenge that can critically impact the design of thermal protection systems for atmospheric entry. Physics-based models of the surface reactions and heat transfer are needed to better predict performance prior to building expensive test beds to prove material performance. However, for many practical applications multiple competing gas/surface reaction paths represent too many unknowns to easily quantify. Despite significant progress in developing better gas-phase and surface chemistry models, there is a marked lack of experimental data for validation/verification of these new models. Recent focused investigations of simple single- and dual- path surface catalyzed recombination reactions have demonstrated that measurements of reactive species fluxes arriving at the surface can be used to quantify reaction rates and recombination efficiencies. These measurements have provided useful information for physics-based gas/surface interaction model development. Unfortunately, these measurements have not answered the fundamental question of energy conservation: how much chemical energy is deposited on the surface and how much energy leaves with the recombined molecules? Species-specific chemical heating is a fundamental component of convective heat transfer to surfaces in high-enthalpy plasma flows such as those found over atmospheric entry vehicles. An experimental effort to investigate energy transport to materials in highly dissociated air plasma streams in the UVM 30 kW Inductively Coupled Plasma (ICP) Torch Facility is proposed. This effort will require the development and application of laser diagnostic strategies to quantify the energy state of the molecules leaving the surface, including rotational, vibrational, and electronic energy. Recent work has shown that NO is formed preferentially over N_2 and O_2 in air plasmas. Laser diagnostics for NO detection in the ICP facility have been proven, and these will be used to quantify the NO concentrations and energy distributions at the surface, and to make the balance between arriving and departing energy fluxes. Together with heat transfer measurements for the stream, these measurements will allow us to assign the amount of energy deposited by recombination. Although other surface reactions may be more important, NO represents a useful test case for laser measurements and theoretical development. The proposed research will provide unique experimental data that will fully characterize the chemical component of convective heat transfer at surfaces exposed to air plasmas. The chemical heating component is the most difficult to quantify and model. The proposed measurements of species populations, concentration gradients, and energy states will finally address energy accommodation at air plasma-surface interfaces in a species-specific and comprehensive manner. Such measurements address a critical need in NASA Technology Area 09: Entry, Descent, and Landing Systems. More specifically, this work will provide data to support improvements in numerical models of thermal protection systems (9.1.6 and 9.4.5). Impact beyond these specific areas will follow from reduction of modeling uncertainties, which will

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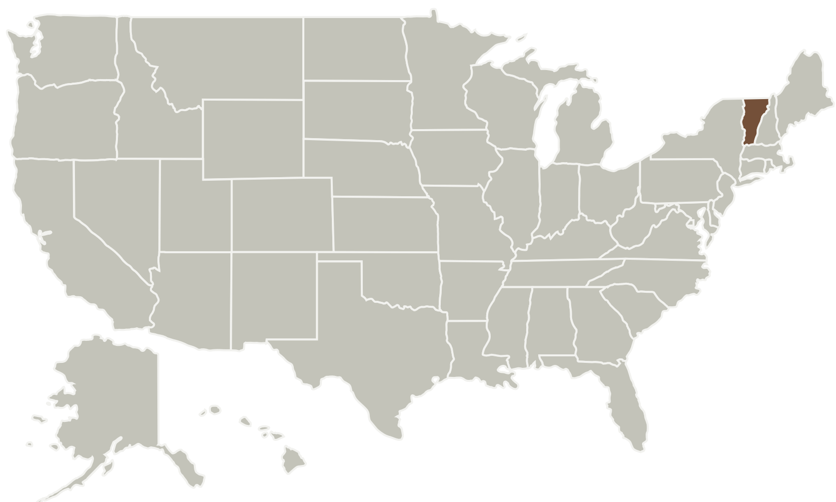
lead to lower mass margins for thermal protection, thereby providing greater scientific payload capacity.

Anticipated Benefits

This work will provide data to support improvements in numerical models of thermal protection systems (9.1.6 and 9.4.5). Impact beyond these specific areas will follow from reduction of modeling uncertainties, which will lead to lower mass margins for thermal protection, thereby providing greater scientific payload capacity.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Vermont	Lead Organization	Academia	Burlington, Vermont

Primary U.S. Work Locations
Vermont

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Vermont

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

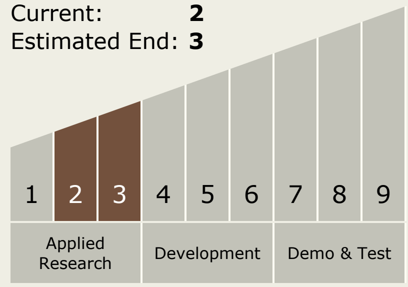
Douglas G Fletcher

Co-Investigator:

Roland Herrmann-stanzel

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.4 Vehicle Systems
    └ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Foundational Knowledge